

NASA Science Mission Directorate

Earth Science Division

Applied Sciences Program



Integrating GRACE and GRACE Follow On Data into Flood and Drought Forecasts for the Continental U.S.

PI: Matthew Rodell

***NASA Water Resources PI Meeting
April 26-28, 2016***



Project Team

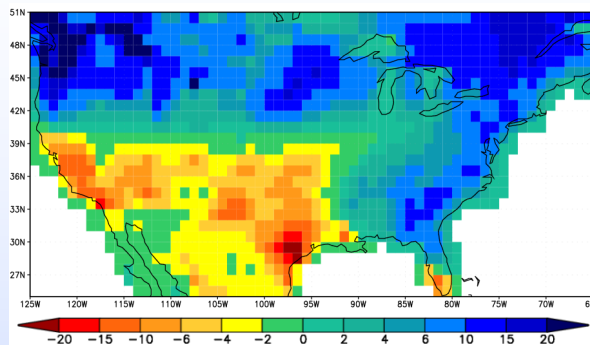
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Co-I	Mark Svoboda	University of Nebraska / NDMC
Co-I	Brian Wardlow	University of Nebraska / NDMC
Co-I	Pedro Restrepo	NOAA North Central River Forecast Center
Co-I	Elizabeth Nelsen	U.S. Army Corps of Engineers
Co-I	Rich Schueneman	U.S. Army Corps of Engineers
Co-I	Srinivas Bettadpur	The University of Texas
Co-I	Rolf Reichle	NASA/GSFC
Co-I	Sujay Kumar	NASA/GSFC
Res. Assoc.	Augusto Getirana	U. Maryland and NASA/GSFC



GRACE Data Assimilation for Drought Monitoring



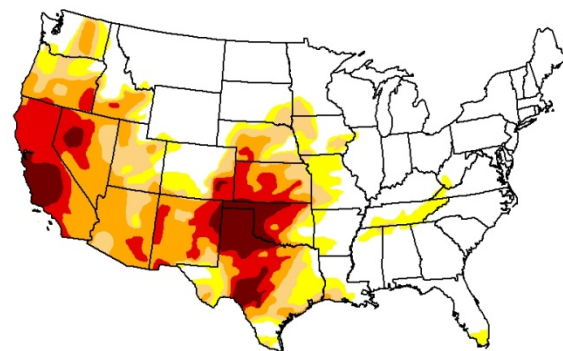
GRACE terrestrial water storage anomalies (cm equivalent height of water) for May 2014 (Tellus CSR RL05 scaled).



New process integrates data from GRACE and other satellites to produce timely information on wetness conditions at all levels in the soil column, including groundwater. For current maps and more info, see <http://www.drought.unl.edu/MonitoringTools.aspx>

U.S. Drought Monitor CONUS

May 20, 2014
(Released Thursday, May 22, 2014)
Valid 8 a.m. EDT



Intensity

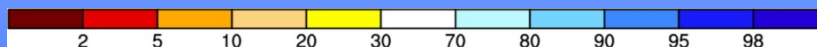
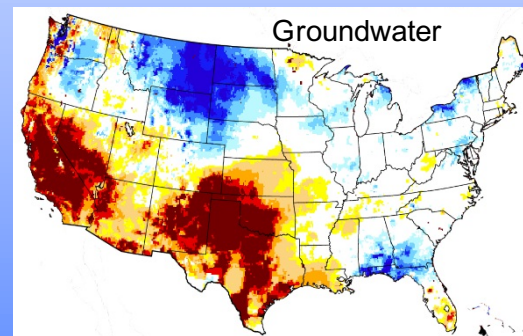
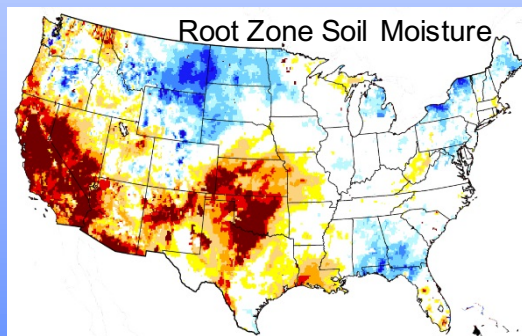
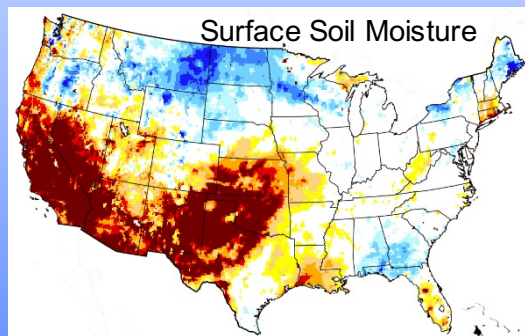
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Michael Brower
NCCO/NOAA

USDA
<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor product for 20 May 2014.



Drought indicators from GRACE data assimilation (wetness percentiles relative to the period 1948-present) for 19 May 2014.

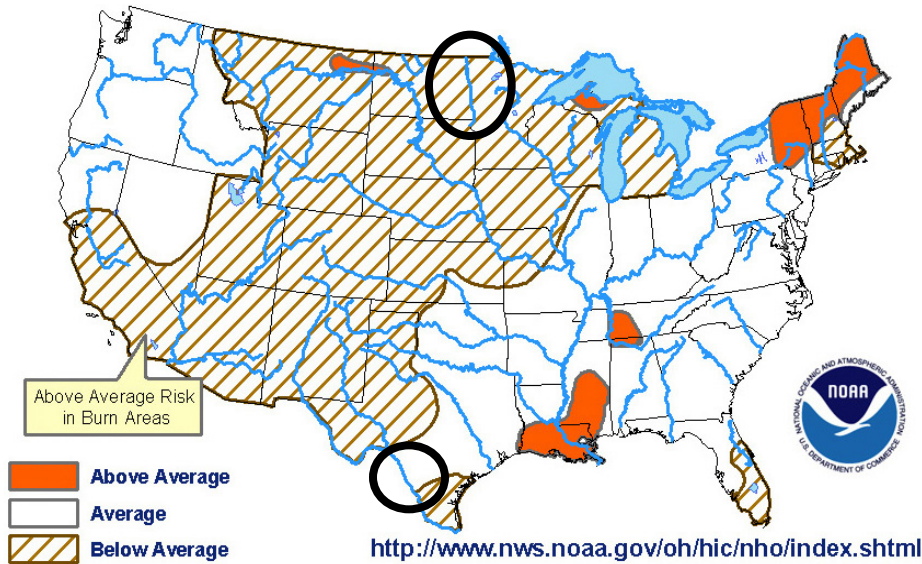
Statement of challenges / need / opportunity

- Reliable drought forecasts would be more valuable than maps of current drought conditions.
- River flow forecasts would benefit from more accurate antecedent wetness conditions.
- Terrestrial water storage (TWS) data from GRACE can be spatially and temporally downscaled and vertically disaggregated via integration with other observations within a land surface model, and the resulting soil moisture and groundwater fields are useful for drought monitoring and flood vulnerability assessment.
- TWS has significant “memory”, hence it contains valuable information on antecedent conditions that influence flood and drought severity.

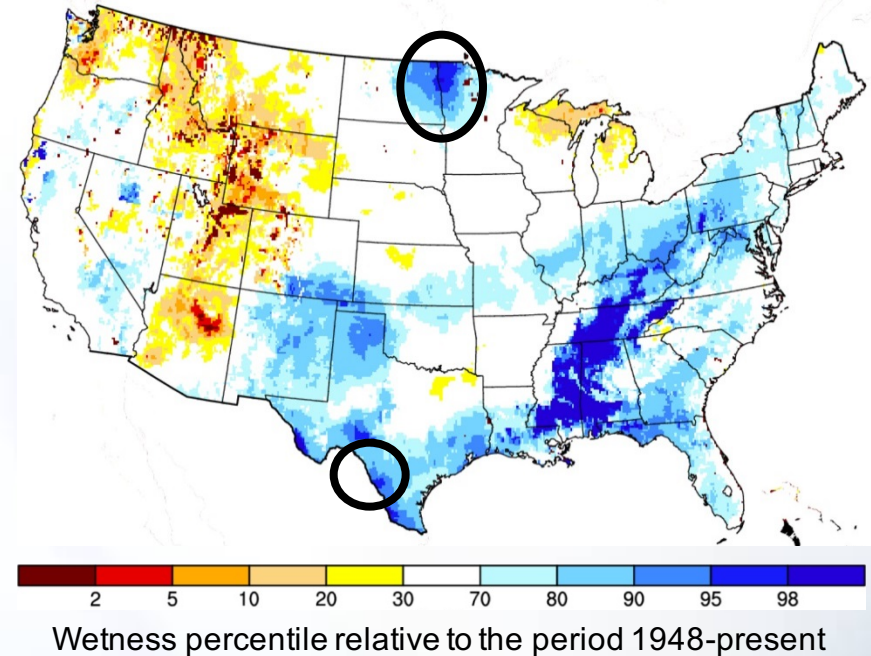
GRACE Based Flood and Drought Forecasts



**NOAA's Spring Flood Risk Assessment
Issued March 12, 2004**



**Shallow Groundwater Drought/Wetness
Indicator from GRACE DA, March 8, 2004**



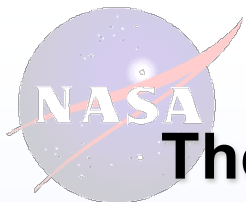
From the Dartmouth Flood Observatory

March 28 – April 11, 2004: “Extensive overland flooding in rural areas of the Red River valley.” Dead: none. Displaced: 1,000. Damage: \$4.5M.

April 4-6, 2004 - “Flooding some of the worst in the history of the U.S.-Mexico border region.” Dead: 37. Displaced: 3,500. Damage: ??

Note 1: Wet antecedent conditions are neither a guaranty of nor a prerequisite for flooding.

Note 2: NOAA correctly forecasts spring flooding more often than not.



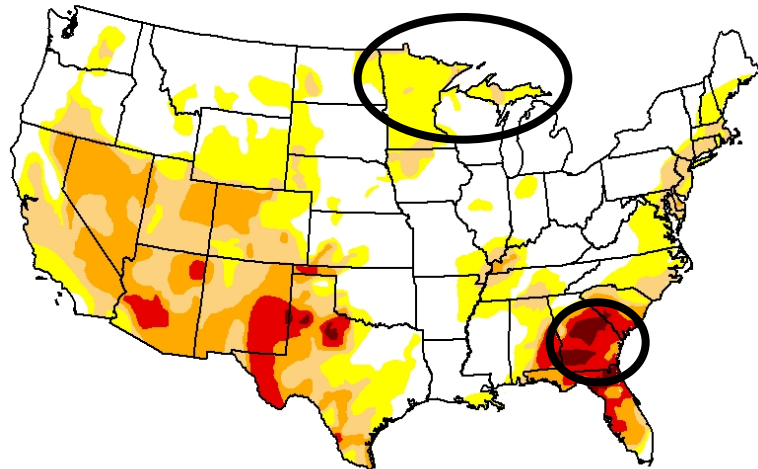
The Persistence of Deep Drought

U.S. Drought Monitor
CONUS

May 15, 2012

(Released Thursday, May. 17, 2012)

Valid 7 a.m. EST



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

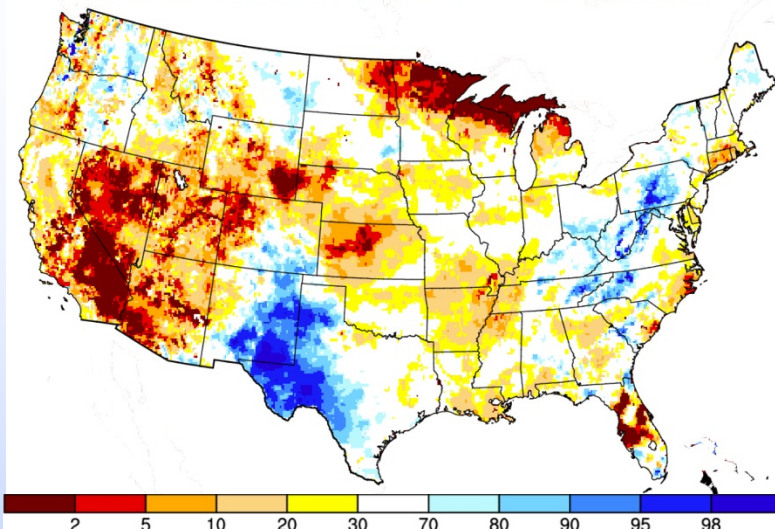
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture



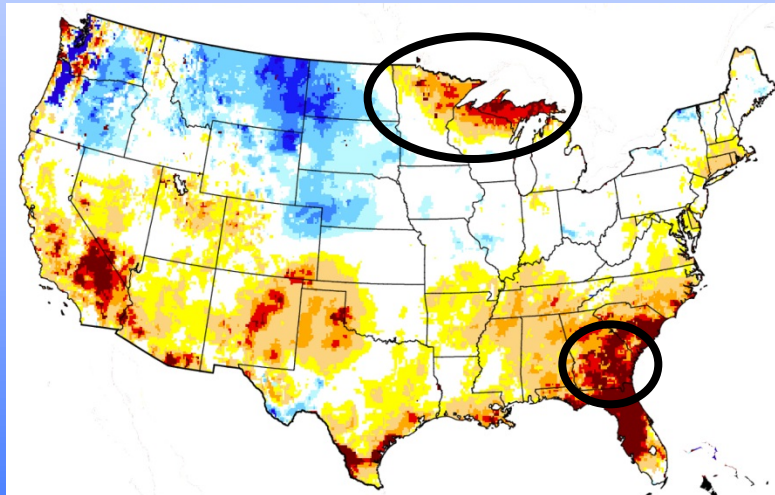
<http://droughtmonitor.unl.edu/>

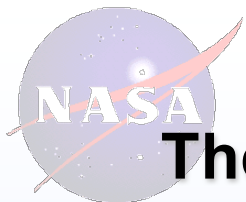
Surface Soil Moisture Drought/Wetness Indicator from GRACE DA, May 14, 2012



Wetness percentile relative to the period 1948-present

Shallow Groundwater Drought/Wetness Indicator from GRACE DA, May 14, 2012

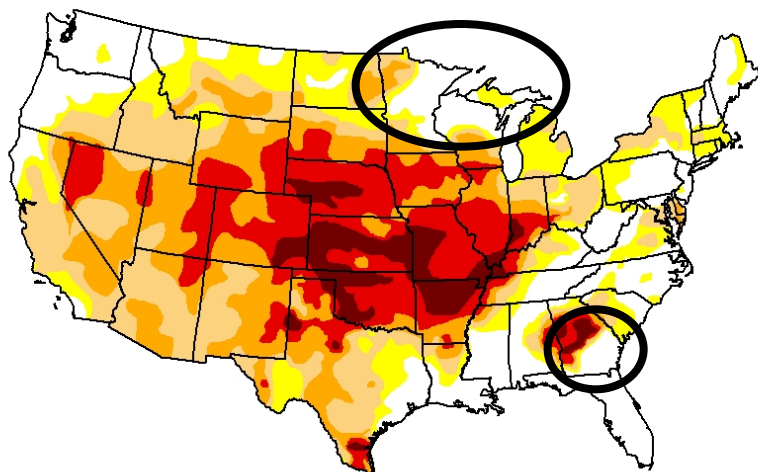




The Persistence of Deep Drought

U.S. Drought Monitor
CONUS

August 28, 2012
(Released Thursday, Aug. 30, 2012)
Valid 7 a.m. EST



Intensity:

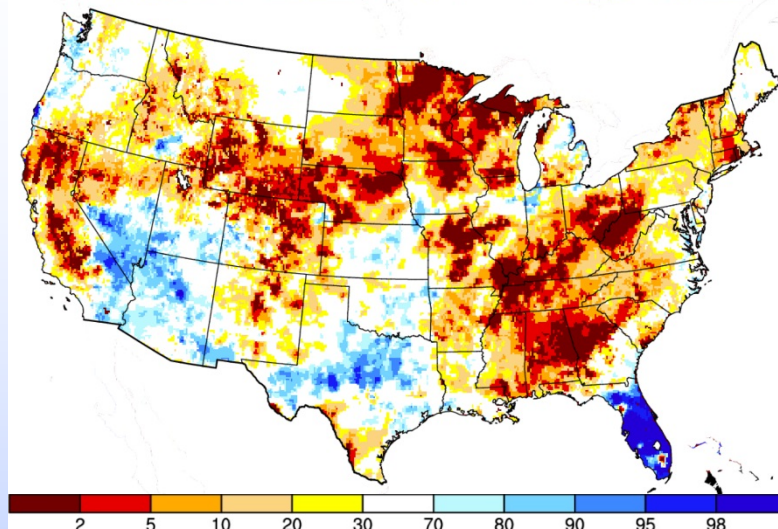
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brian Fuchs
National Drought Mitigation Center

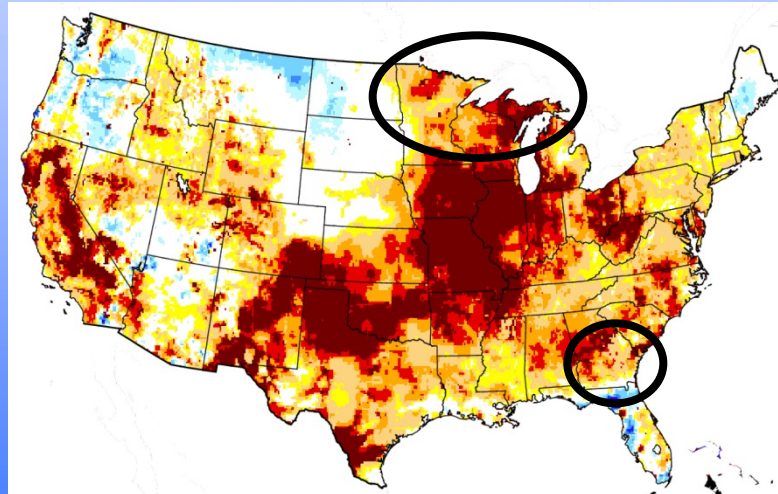


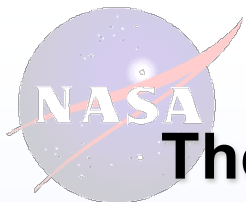
Surface Soil Moisture Drought/Wetness Indicator from GRACE DA, August 27, 2012



Wetness percentile relative to the period 1948-present

Shallow Groundwater Drought/Wetness Indicator from GRACE DA, August 27, 2012

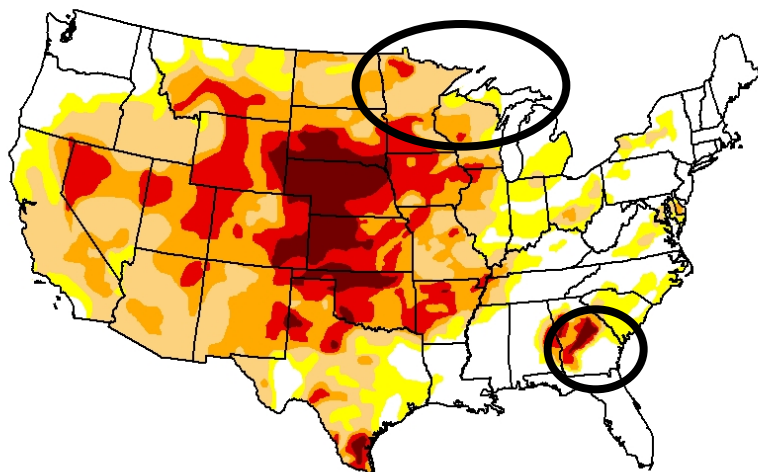




The Persistence of Deep Drought

U.S. Drought Monitor
CONUS

October 23, 2012
(Released Thursday, Oct. 25, 2012)
Valid 7 a.m. EST



Intensity:

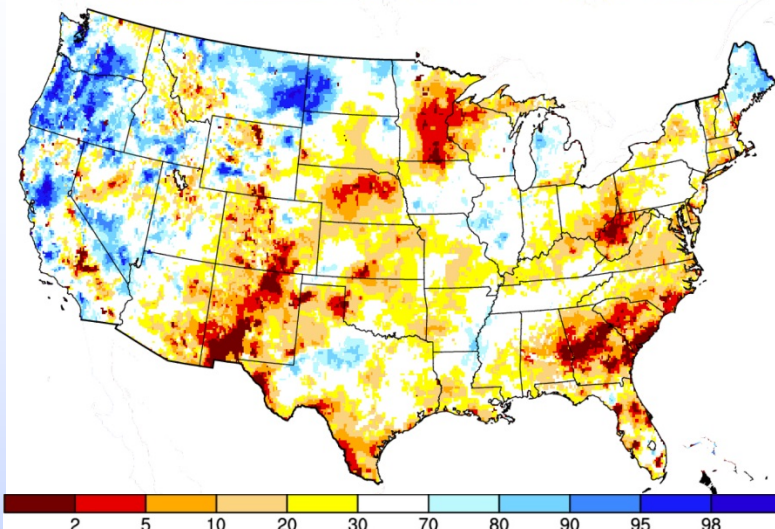
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture

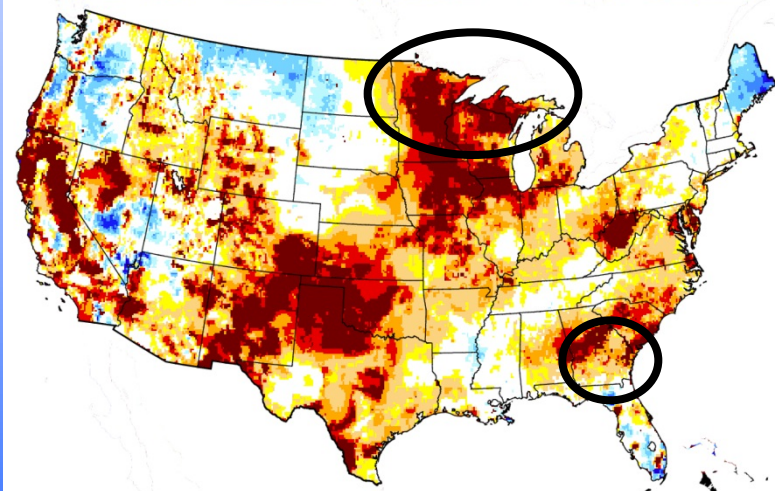


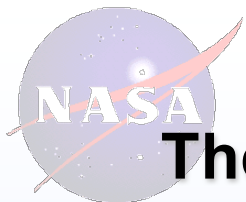
Surface Soil Moisture Drought/Wetness Indicator from GRACE DA, October 23, 2012



Wetness percentile relative to the period 1948-present

Shallow Groundwater Drought/Wetness Indicator from GRACE DA, October 23, 2012

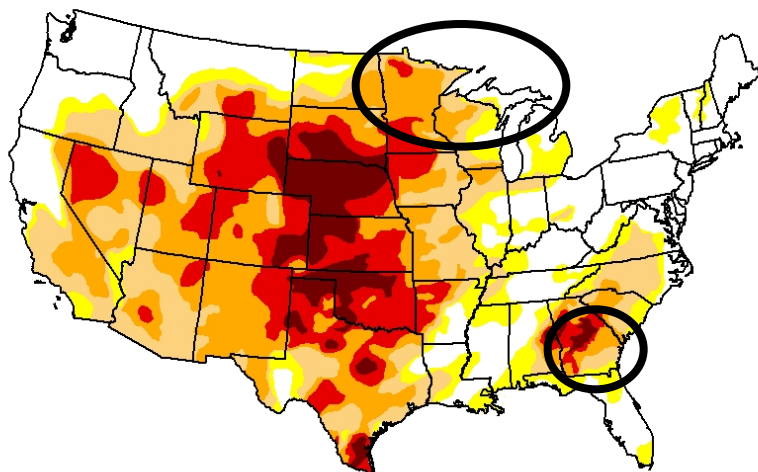




The Persistence of Deep Drought

U.S. Drought Monitor
CONUS

December 25, 2012
(Released Thursday, Dec. 27, 2012)
Valid 7 a.m. EST



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

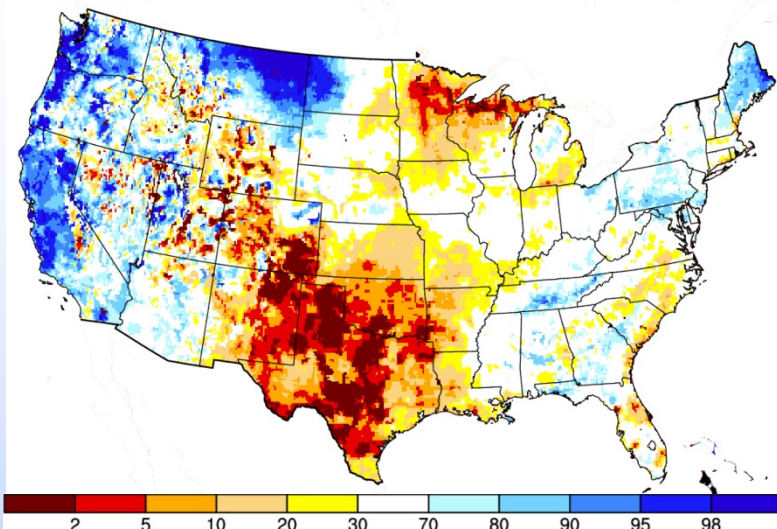
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Heim
NCDC/NOAA



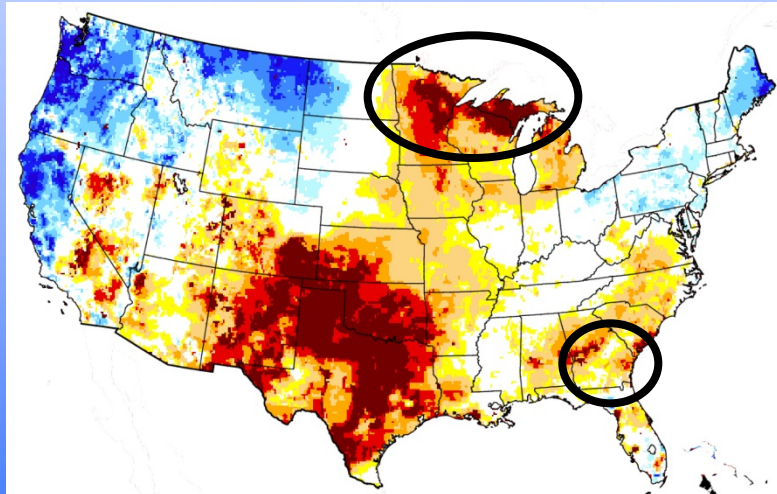
<http://droughtmonitor.unl.edu/>

Surface Soil Moisture Drought/Wetness
Indicator from GRACE DA, December 24, 2012



Wetness percentile relative to the period 1948-present

Shallow Groundwater Drought/Wetness
Indicator from GRACE DA, December 24, 2012



Key datasets, models, scientific, technical tools

Datasets:

- Terrestrial water storage anomalies from GRACE and GRACE-FO
 - New “regularized” and low-latency hydrology products developed by our Co-Is at the University of Texas
- Princeton and NLDAS-2 meteorological forcing
- NASA GEOS-5 seasonal forecasts

Land Surface Model:

- NASA’s Land Information System (LIS) driving the Catchment Land Surface Model with gridded GRACE data assimilation.

Technical Tools:

- NOAA/NCRFC’s operational river forecast system
- USACE’s reservoir management decision support tools



Approach (very brief overview)

- 1948-present retrospective simulation for background climatology.
- Gridded GRACE (and GRACE FO) data assimilation for 2002-present.
- Downscale GEOS-5 seasonal forecasts using 3 approaches: (1) Bayesian merging, (2) bias correction and spatial downscaling, (3) hybrid analog.
- Drive Catchment LSM with downscaled forecasts, starting from data assimilation based initial conditions.
- Drought forecast development and testing.
- River flow forecast development and testing.
- Data distribution and transition to operations.



Anticipated Impacts

- Improved skill and reduced uncertainty in short term to seasonal river flow forecasts.
- Innovative 30-90 day drought forecasts for the continental U.S.
- Improved short term to seasonal flood vulnerability assessments.

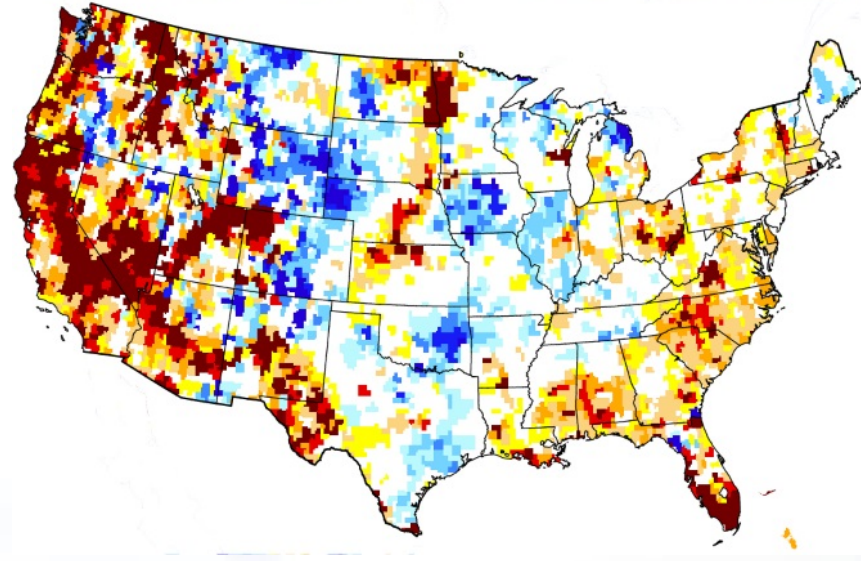
Current partners and user community

Role	Organization Name	Organization Type
Partner	National Drought Mitigation Center	NGO/Data Distributor
Partner/End User	NOAA NCRFC	Federal Agency
Partner/End User	U.S. ACE	Federal Agency
End User	U.S. Drought Monitor	Multi-user DSS
End User	NIDIS	Federal Multi-Agency Organization
Stakeholder	Farmers, water resources managers, industry, and others who need reliable drought and water availability forecasts	Private Sector Commercial

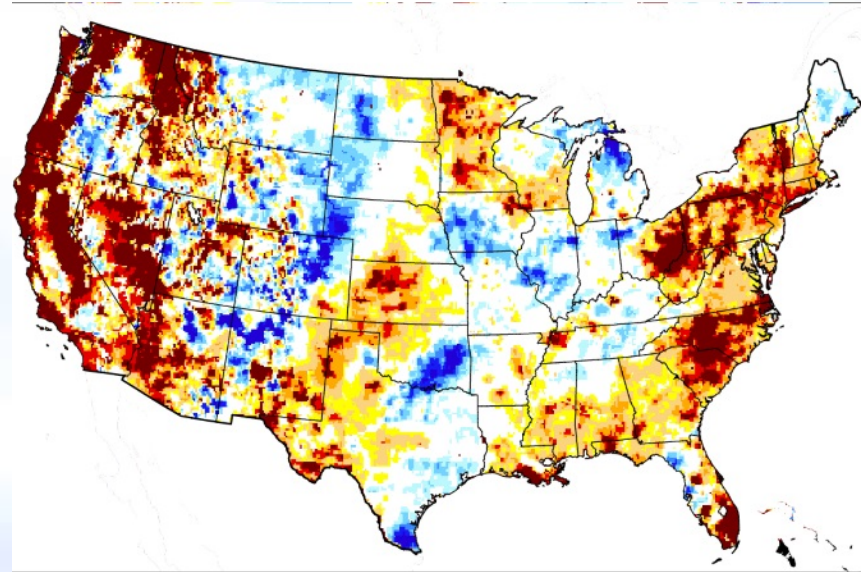
GRACE Based Flood and Drought Forecasts



Groundwater wetness/drought indicators from basin-average GRACE data assimilation (DA) at 0.25° (top) and from gridded GRACE DA within LIS at 0.125° (bottom), valid 14 September 2015. Note the improvement in pattern definition.



0.25°

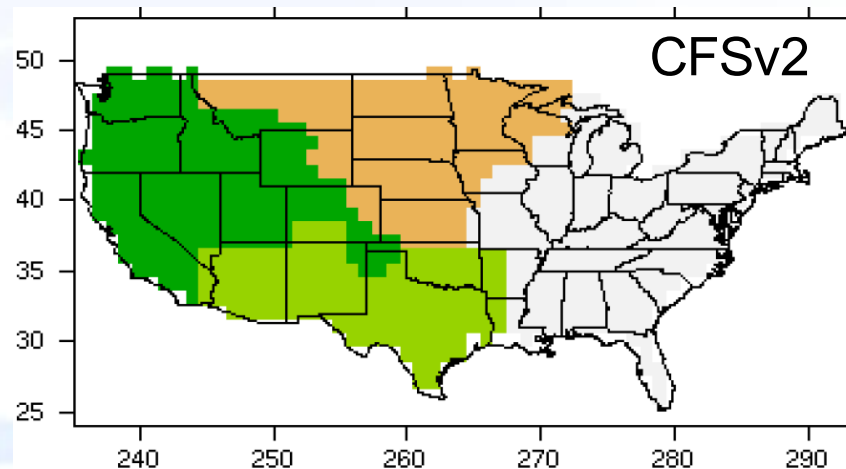
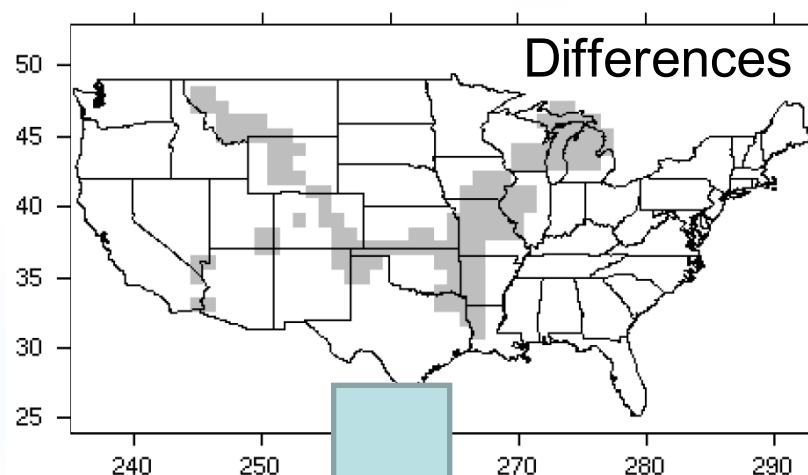
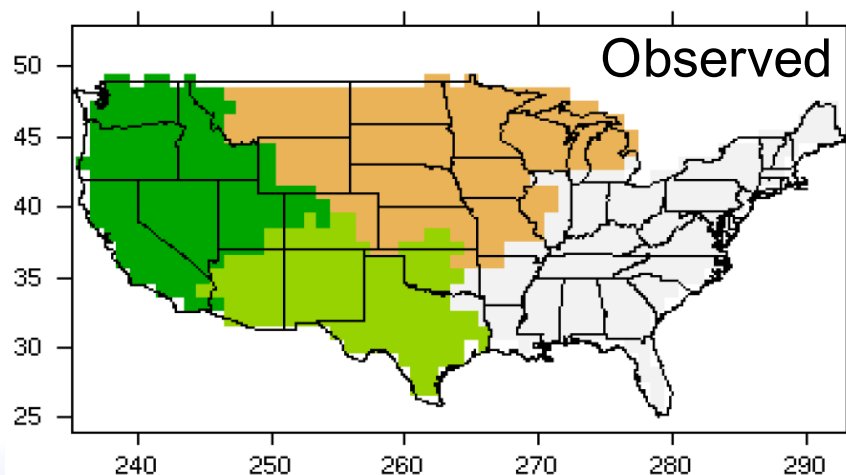


0.125°

Wetness Percentile



GRACE Based Flood and Drought Forecasts



- Forecast skill is **significantly worse** in zones of regional disagreement.
- **Analogous region downscaling methods** are needed in these areas

Objective Regionalization of observed and CFSv2 forecast rainfall (May-Sep)



Near Term Objectives

- NASA/GSFC is continuing to refine the model and DA parameters.
- NDMC is designing a new GRACE DA wetness indicator product distribution webpage.
- JHU continues to work on objective regionalization of the CONUS and downscaling of seasonal forecasts.
- U. Texas is preparing and NASA/GSFC is testing quick-look (low latency) GRACE hydrology fields.
- U. Texas is refining (with NASA/GSFC input) a daily GRACE swath product.
- NOAA/NCRFC is investigating (retrospectively) the value of GRACE DA groundwater, soil moisture, and SWE outputs for runoff/flood forecasting.



Transition Strategy

- Drought/wetness forecasts to be added to existing suite of GRACE-based products at the National Drought Mitigation Center.
- GRACE based wetness conditions to be incorporated into NOAA/NCRFC's river forecasting tools.
- Transition to be seamless for USACE, who will continue to use river flow products from NCRFC.



Lessons Learned

- Flexibility is key – don't expect everything to go as planned or scheduled; continuing to make progress is more important.
- Make it easy for end users to provide feedback or ask questions about your product, then take the opportunity to learn how they use the data and what are their needs.